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# TYPE I COSMIC SPHERULES: KEY TO A MAJOR, BUT POORLY SAMPLED, ASTEROID POPULATION?

L. E. Nyquist, Mail Code SN2, NASA Johnson Space Center, Houston, TX 77058, l.nyquist@jsc.nasa.gov.

**Introduction:** Herzog *et al.* [1] have determined Fe, Ni, and Cr abundances in Type I cosmic spherules recovered from the deep sea, and also the isotopic fractionation of these elements during passage of the spherules through the terrestrial atmosphere. Isotopic fractionation for all three elements is typically large,

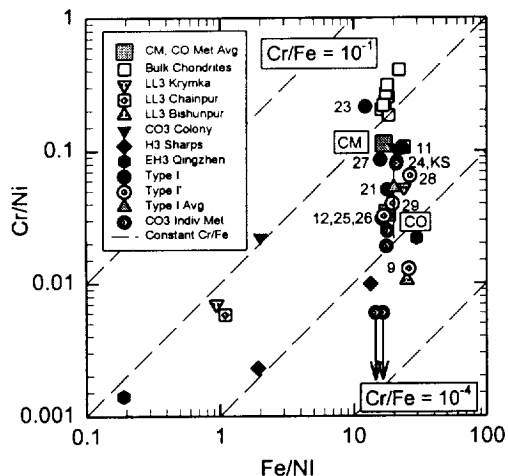


Figure 1. Pre-atmospheric Fe/Ni and Cr/Ni ratios for Type I spherules compared to those in bulk chondrites and chondritic metal [1]. Arabic numerals designate individual spherules. Type I' are spherules for which some parameters were determined by interpolation. Cr/Ni ratios for the majority of the spherules lie within the range for average metal from CM and CO chondrites. Metal from individual CO3 meteorites of high metamorphic grade can have lower Cr/Ni ratios as illustrated by downward-pointing arrows for metal from the CO3 meteorites Warrenton and Isna. Data sources are given in [6].

~16‰/amu, corresponding to evaporative mass losses of ~80-85%, assuming Rayleigh distillation from an open system. The corrected, pre-atmospheric, Cr/Ni and Fe/Ni ratios are shown in Figure 1, where they are compared to these ratios in bulk chondrites and chondritic metal. Although the calculated pre-atmospheric Fe/Ni ratio for the spherules is relatively constant at  $19 \pm 4$  ( $\sigma_{\text{mean}}$ ), the calculated pre-atmospheric Cr/Ni ratios vary by about two orders of magnitude. The Cr/Ni ratios are thus powerful discriminators for possible modes of origin of the spherules. For example, iron meteorites typically have low Cr contents and low Cr/Ni ratios,  $\leq 3 \times 10^{-4}$ . Thus, Type I spherules do not appear to be ablation products of iron meteorites, in contrast to an earlier suggestion [2].

**Possible Origin of the Type I Spherules:** The Type I spherules may stem from a variety of origins, but the one most obviously implied by the Fe, Ni, and Cr data is most interesting. Could the type I precursors be metal grains from carbonaceous chondrites? The most common asteroid spectral types resemble those of carbonaceous chondrites, but the orbits of the corresponding asteroids are not favorably situated to allow material from them to reach the earth [3]. Small particles, however, can be moved out of their dynamically determined orbits by Poynting-Robertson drag. The masses of the spherules analysed by [1] were  $\sim 10^{-4}$  g. A  $10^{-4}$  g stony micrometeoroid has a Poynting-Robertson lifetime at 1 AU of  $\sim 3 \times 10^5$  yr [4]. The P-R lifetime scales proportionally to particle radius, density, and the square of the orbital radius [5], so a  $10^{-4}$  g metallic particle initially in a circular orbit at 2.5 AU will have a P-R lifetime of  $\sim 5 \times 10^6$  yr. Collisional lifetimes scale with the strength of the material, so that metallic particles should have much longer collisional lifetimes than stony ones of equivalent mass, probably about an order of magnitude longer [3]. Grün *et al.* [4] calculate the collisional lifetime of a  $10^{-4}$  g stony micrometeoroid as a few times  $10^4$  yr at 1 AU and a few times  $10^2$  yr at 0.1 AU. Thus, collisional lifetimes against destruction on the order of  $10^6$  yr for metallic particles at ~2.5 AU may not be unreasonable. If the collisional lifetime for an ~100  $\mu$ g metallic particle is an appreciable fraction of the P-R lifetime; i.e., the time required for it to fall into the Sun from ~2.5 AU, there will be a significant probability for such a particle to reach a gravitational resonance where gravitational forces will place it more directly into an earth-crossing orbit. Thus, Type I spherules may be particularly hardy space travelers capable of routinely reaching Earth from places in the asteroid belt from which Earth is otherwise inaccessible.

A possible objection to origin of the Type I spherules from metallic grains from carbonaceous chondrite-like asteroidal parent bodies is the fine-grained nature of the metal in most carbonaceous chondrites. However, some CO chondrites are surprisingly metal-rich. Rubin *et al.* [6] estimated an original metallic (Fe,Ni) abundance of ~19 wt % for CO3 Colony, for example. Furthermore, metal in CO chondrites often occurs in "type-I chondrules" which are spongy-looking in thin section due to their high metal abundance [7].

**Conclusions and Implications:** The high Cr abundance of Type I cosmic spherules show that it is a

mistake to dismiss them as simply atmospheric ablation products of iron meteorites. On the contrary, they may contain among them our only samples of some carbonaceous asteroids which are poorly represented, if at all, among our larger meteorites. Particularly good candidates for such materials are the spherules with Cr/Ni  $\sim 0.02$ -0.1 (Figure 1). That such spherules are relatively abundant among the Type I's suggest that they represent a major main belt asteroid type.

Efforts to collect Type I spherules, especially from the Antarctic ice where a depositional stratigraphy might be preserved, should continue. Analysis of this material, altered as it is, may yield new insights into the nature of some primitive asteroids which have otherwise been poorly sampled. Analysts should bare in mind, however, that most Type I spherules have lost  $\sim 80$ -90% of their Fe, the major remaining component.

Thus, interelement fractionation is to be expected. Although such fractionation appears not to have significantly affected the relative proportions of Fe, Ni, and Cr in Type I's, this simple result should not be expected for elements which differ more in their volatility.

**References:** [1] Herzog G. F. *et al.*, (1999) *Geochim. Cosmochim. Acta*, 63, in press. [2] Blanchard M.B., *et al.*, (1980) *Earth and Planetary Sci. Lett.* 46, 178-190. [3] Chapman C. R. (1976) *Geochim. Cosmochim. Acta*, 40, 701-719. [4] Grün E., *et al.* (1985) *Icarus* 62, 244-272. [5] Wyatt S. P. and Whipple F. L. (1950) *Ap. J.*, 111, 558-565. [6] Rubin A. E., *et al.* (1985) *Meteoritics*, 20, 175-196. [7] McSween H. Y. (1977) *Geochim. Cosmochim. Acta* 41, 477-491.